The FMS-to-QT Connection Scheme

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Starting in the 2008/2009 RHIC running period we are aiming to trigger on clusters in the FMS. A cluster is characterized by a central cell, with a high ADC value, surrounded by eight neighbors with greater-than-average ADC values. The trigger algorithm will aim to detect the central cell, form the sum of the ADC values of all nine cells and then apply a threshold cut to that sum.

The trigger will be implemented at Level 0, i.e. in the QT-DSM tree. In order to maximize the trigger efficiency it will be necessary to trigger on clusters that span boundaries within the electronics chain. Reconstructing clusters that span boundaries is relatively difficult to do in the QT-DSM tree so it seems sensible to arrange the connections between the FMS cells, the QT boards and the DSM boards in such a way as to minimize the probability of a cluster spanning boundaries. Since the majority of the data will be in the small cells, the scheme that is described here has been optimized to minimize the number of small-cell clusters that are split between multiple layer-0 DSM boards. The scheme also makes it as easy as possible to reconstruct those small-cell clusters that do still span multiple layer-0 DSM boards. Unfortunately, this optimization has some negative consequences for the large cells that will also be discussed.

The FMS cells are assigned to QT cards using a geometrical scheme composed of a large set of simple rectangles. The assignment of FMS cells to the 4 QT8 cards within each QT card has been done using a "striping" scheme, where the stripes run along the length of the rectangles. This scheme is shown in Figure 1.

- All of the FMS cells that connect to the DSM tree are shown in Figure 1.
- The cells that are contained within a thin solid line are all connected to one QT card.
- Within each QT card the thick solid line marks the locations of clusters that are totally contained by that QT card.
- In 3 of the 4 quadrants the stripes, indicating which QT8 card a cell is assigned to, are shown in light and dark gray.
- In the upper right quadrant the stripes are shown in shades of blue and yellow.
- In this quadrant each QT card has a label from A to J. The 4 stripes in each QT card (representing the 4 QT8 cards) are labeled from 0 to 3. In the rest of this document individual QT8 cards are referred to using these reference numbers, e.g. A(1). E(0), etc….
- Finally, the cells are separated out into 3 groups, indicating which QT card is connected to each of 3 layer-0 DSMS.

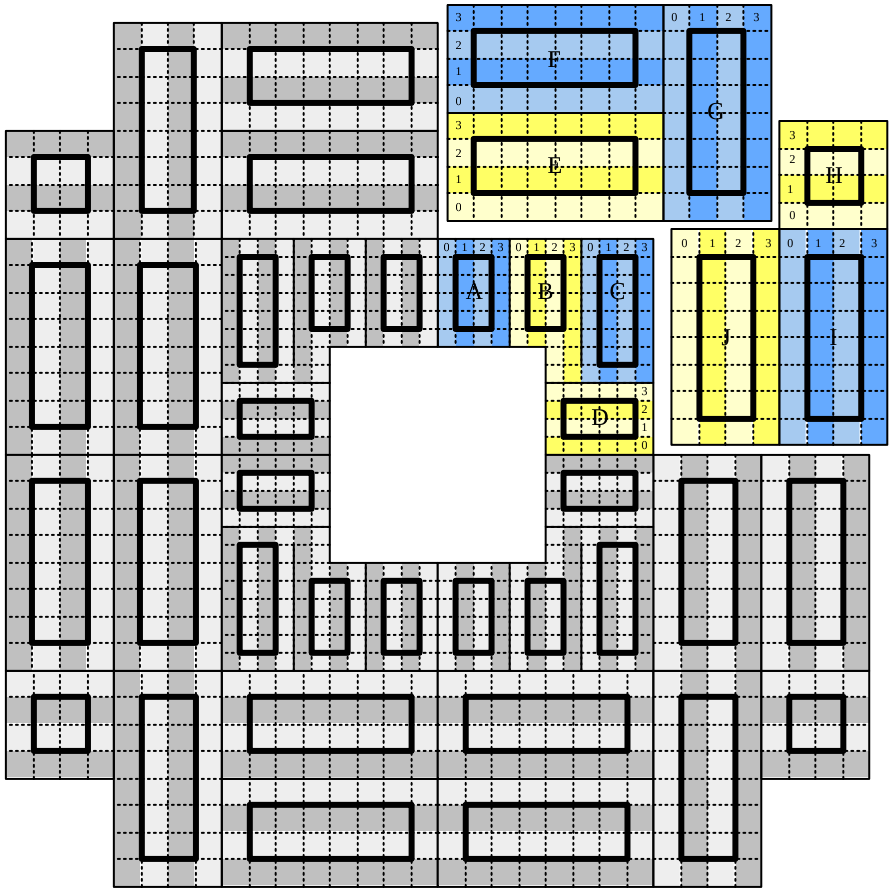

Figure 1: FMS Cell to QT and Layer-0-DSM Assignment Scheme

A cluster is then reconstructed by summing together the QT8-sum, from the stripe that contains the high tower, with the stripes on either side of it:

Cluster-sum = QT8-sum(stripe(HT)) + QT8-sum(stripe-1) + QT8-sum(stripe+1)

This logic is simple to code in VHDL. So long as all 3 stripes are within one layer 0 DSM it doesn't matter which QT card they come from. However, when the cell that contains the high tower, i.e. the center of the cluster, lays on the edge a DSM's region, then things become more complicated.

Table 1 shows the list of QT8 sums that need to be used to reconstruct a cluster located in the cells of the upper-right quadrant of the FMS, i.e. the colored part of Figure 1. For each QT card, Table 1 contains the list of QT8 cards for all 4 corner cells, and then 1 example from the cells on each of the 4 sides and 1 example from an interior cell.

The columns in Table 1 are:

- DSM Board: The name of the layer 0 DSM board to which this FMS cell is ultimately connected
- QT: QT board reference letter from A to J

- HT ID: ID of cell with the highest ADC value, which then forms the center of the cluster:

ID	QT8
0:7	0
8:15	1
16:23	2
24:31	3

- Loc.: Geometric location of this cell (HT ID) within the block of cells connected to this QT card:
  - TL = top left
  - L = left
  - BL = bottom left
  - T = top
  - I = internal
  - B = bottom
  - TR = top right
  - R = right
  - BR = bottom right
- List: A list of the QT8 sums that need to be added together to reconstruct this cluster. Only those QT8 sums that are available within this layer-0 DSM board are shown
- No.: The number of cells that use this list. For the corner cells (TL, BL, TR, BR) this number if always 1. For the edge and interior cells the number ranges from 2 to 12.
- Comment: A list of the other QT8 sums that still need to be added in to complete this cluster. Those QT8 sums are in other layer-0 DSMS and can be added in either at layer-1 or layer-2 of the DSM tree. “Done” means that the cluster is complete.

Table 1: QT8 Lists for Cluster Reconstruction in Upper-Right Quadrant of the FMS

DSM Board	QT	HT ID	Loc.	List	No.	Comment
FM001	A	0	TL	A(0), A(1)	1	Add in E(0) at layer 1 and then 2 more sums from next quadrant at layer 2
		3	L	A(0), A(1)	4	Add in 1 sum from next quadrant at layer 2
		5	BL	A(0), A(1)	1	Add in 1 sum from next quadrant at layer 2
		8	T	A(0), A(1), A(2)	2	Add in E(0) at layer 1
		9	I	A(0), A(1), A(2)	8	Done
		21	B	A(1), A(2), A(3)	2	Done
		24	TR	A(2), A(3), B(0)	1	Add in E(0) at layer 1
		26	R	A(2), A(3), B(0)	4	Done
		29	BR	A(2), A(3), B(0)	1	Done
	B	0	TL	A(3), B(0), B(1)	1	Add in E(0) at layer 1
		3	L	A(3), B(0), B(1)	4	Done
		5	BL	A(3), B(0), B(1)	1	Done
		8	T	B(0), B(1), B(2)	2	Add in E(0) at layer 1
		9	I	B(0), B(1), B(2)	11	Done
		23	B	B(2), B(3), D(3)	1	Done
		24	TR	B(2), B(3), C(0)	1	Add in E(0) at layer 1
		26	R	B(2), B(3), C(0)	6	Done
		31	BR	B(2), B(3), C(0), D(3)	1	Done
	C	0	TL	B(3), C(0), C(1)	1	Add in E(0) at layer 1
		3	L	B(3), C(0), C(1)	6	Done
		7	BL	B(3), C(0), C(1), D(3)	1	Done
		8	T	C(0), C(1), C(2)	2	Add in E(0) at layer 1

		9	I	C(0), C(1), C(2)	12	Done
		23	B	C(1), C(2), C(3), D(3)	2	Done
		24	TR	C(2), C(3)	1	Add in E(0), G(0) and J(0) at layer 1
		26	R	C(2), C(3)	6	Add in J(0) at layer 1
		31	BR	C(2), C(3), D(3)	1	Add in J(0) at layer 1
	D	0	BR	D(0), D(1)	1	Add in J(0) at layer 1 and then 2 more sums from next quadrant at layer 2
		3	B	D(0),D(1)	4	Add in 1 sum from next quadrant at layer 2
		5	BL	D(0), D(1)	1	Add in 1 sum from next quadrant at layer 2
		8	R	D(0), D(1), D(2)	2	Add in J(0) at layer 1
		9	I	D(0), D(1), D(2)	8	Done
		21	L	D(1), D(2), D(3)	2	Done
		24	TR	C(2), C(3), D(2), D(3)	1	Add in J(0) at layer 1
		26	T	C(0),C(1),C(2),D(2),D(3)	4	Done
		29	TL	B(2), B(3), D(2), D(3)	1	Done
FM002	E	0	BL	E(0),E(1)	1	Add in A(0), A(1) and A(2) at layer 1 and then 3 more sums from next quadrant at layer 2
		3	B	E(0), E(1)	6	Add in B(0), B(1) and B(2) at layer 1
		7	BR	E(0), E(1), G(0)	1	Add in C(1), C(2), C(3) and J(0) at layer 1
		8	L	E(0), E(1), E(2)	2	Add in 3 more sums from next quadrant at layer 2
		9	I	E(0), E(1), E(2)	12	Done
		23	R	E(1), E(2), E(3), G(0)	2	Done
		24	TL	E(2), E(3), F(0)	1	Add in 3 more sums from next quadrant at layer 2
		26	T	E(2), E(3), F(0)	6	Done
		31	TR	E(2), E(3), F(0), G(0)	1	Done
	F	0	BL	E(3), F(0), F(1)	1	Add in 3 more sum from the next quadrant at layer 2
		3	B	E(3), F(0), F(1)	6	Done

		7	BR	E(3), F(0), F(1), G(0)	1	Done
		8	L	F(0), F(1), F(2)	2	Add in 3 more sums from the next quadrant at layer 2
		9	I	F(0), F(1), F(2)	12	Done
		23	R	F(1), F(2), F(3), G(0)	2	Done
		24	TL	F(2), F(3)	1	Add in 2 more sums from the next quadrant at layer 2
		26	T	F(2), F(3)	6	Done
		31	TR	F(2), F(3), G(0)	1	Done
	G	0	TL	F(2), F(3), G(0), G(1)	1	Done
		3	L	E(3),F(0),F(1),G(0),G(1)	6	Done
		7	BL	E(0), E(1), G(0), G(1)	1	Add in C(1), C(2), C(3), J(0) and J(1) at layer 1
		8	T	G(0),G(1),G(2)	2	Done
		9	I	G(0), G(1), G(2)	12	Done
		23	B	G(1), G(2), G(3)	2	Add in J(1), J(2) and J(3) at layer 1
		24	TR	G(2), G(3)	1	Done
		26	R	G(2), G(3)	3	Done
		29	R	G(2), G(3)	3	Add in H(1), H(2) and H(3) at layer 1
		31	BR	G(2), G(3)	1	Add in H(0), H(1), I(0), J(2) and J(3) at layer 1
FM003	H	0	BL	H(0),H(1),I(0),I(1),J(3)	1	Add in G(3) at layer 1
		1	B	H(0),H(1),I(0),I(1),I(2)	2	Done
		3	BR	H(0), H(1), I(2), I(3)	1	Done
		8	L	H(0), H(1), H(2)	2	Add in G(3) at layer 1
		9	I	H(0), H(1), H(2)	4	Done
		19	R	H(1), H(2), H(3)	2	Done
		24	TL	H(2), H(3)	1	Add in G(3) at layer 1
		26	T	H(2), H(3)	2	Done
		27	TR	H(2), H(3)	1	Done
	I	0	TL	H(0), I(0), I(1), J(3)	1	Add in G(3) at layer 1

		3	L	I(0), I(1), J(3)	6	Done
		7	BL	I(0), I(1), J(3)	1	Add in 3 more sums from the next quadrant at layer 2
		8	T	H(0), I(0), I(1), I(2)	2	Done
		9	I	I(0), I(1), I(2)	12	Done
		23	B	I(1), I(2), I(3)	2	Add in 3 more sums from the next quadrant at layer 2
		24	TR	H(0), I(2), I(3)	1	Done
		26	R	I(2), I(3)	6	Done
		31	BR	I(2), I(3)	1	Add in 2 more sums from the next quadrant at layer 2
	J	0	TL	J(0), J(1)	1	Add in C(3), E(0), G(0) and G(1) at layer 1
		3	L	J(0), J(1)	6	Add in C(3) at layer 1
		7	BL	J(0), J(1)	1	Add in D(0), D(1) and D(2) at layer 1 and then 3 more sums from the next quadrant at layer 2
		8	T	J(0), J(1), J(2)	2	Add in G(0), G(1) and G(2) at layer 1
		9	I	J(0), J(1), J(2)	12	Done
		23	B	J(1), J(2), J(3)	2	Add in 3 more sums from the next quadrant at layer 2
		24	TR	H(0), I(0), J(2), J(3)	1	Add in G(2) and G(3) at layer 1
		26	R	I(0), J(2), J(3)	6	Done
		31	BR	I(0), J(2), J(3)	1	Add in 3 more sums from the next quadrant at layer 2

Table 2 summarizes some information from Table 1. It shows, for each of the 3 layer-0 DSM boards, how many clusters are completely contained by a single QT card, and, more importantly, how many clusters are completely contained within each layer-0 DSM board. These are the clusters that can be fully reconstructed by each layer-0 DSM; they are listed as "Done" in Table 1 and do not need any more data added in. The totals indicate that around 70% of clusters can be completed in the layer-0 DSM boards.

Table 2: Statistics for each Layer 0 DSM

DSM Board	QT Boards connected to this DSM	Cell Type	Total Cells	# of clusters internal to a single QT board		# of clusters internal to this DSM board	
				#	% of Total	#	% of Total
FM001	A, B, C and D	Small	108	36	33	75	69
FM002	E, F and G	Large	96	36	37	74	77
FM003	H, I and J	Large	80	28	35	57	71

Table 3 then shows which QT8 sums are still needed to complete the remaining small-cell clusters, and shows how many bits need to be passed from each layer-0 DSM to the layer-1 DSM. The bit counts are all less than 32, which is the maximum that can be passed from one DSM to another, so there is no problem passing these bits.

Table 3: Data to be passed on to Layer 1 to complete the Small Cell Clusters

DSM Board	Data to be Passed to Layer-1 DSM				
	Cluster Data	# of Bits	Additional Data to complete Small Cell Clusters	# of Bits	Total # of Bits
FM001	Largest sum Flag	7 3	A(0) D(0)	5 5	20
FM002	Largest sum Flag	8 3	E(0) G(0)	5 5	21
FM003	Largest sum Flag	8 3	J(0)	5	16

A serious problem does exist if it is also necessary to pass enough data to complete the remaining large cell clusters. From looking at Figure 1 it is clear, for example, that if a cluster is located (HT ID) somewhere in the E(0) QT8 card (i.e. on the large-cell side of the boundary between large and small cells) then it will be necessary to have access to all of the A(0):C(3) QT8 sums to complete this cluster. The A(0):C(3) QT8 sums would need to be passed from their layer-0 DSM board (FM001) up to the layer-1 DSM board, and there are not enough bits available to pass all of these 12 5-bit numbers. A similar problem occurs on the boundary between the D and J QT cards, where the orientation of the stripes change, and on the quadrant boundaries between large cells. Since there are not enough bits available to pass all the information, it will be not possible to complete the remaining large cell clusters in this scheme.